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ENGINEERING STUDY OF JET AIRMIX FIRE SUPPRESSION

by

Fred L. McIntyre

August 1975

Revised October 22, 1975

NASA NATIONAL SPACE TECHNOLOGY LABORATORIES
General Electric Company
Engineering and Science Services Laboratory
Bay Saint Louis, Mississippi 39520

Contract No. NAS8-27750

U.S. ARMY ARMAMENT COMMAND

DEPARTMENT OF THE ARMY
Headquarters, Edgewood Arsenal
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Present state of the art technology is cable of preventing the occurrence of catastrophic events in the event of a dust explosion. A rupture disk satisfies the criteria for venting and an ultraviolet type sensor satisfies the criteria for detection. A manufactures' survey indicates that of the self items with minimum delivery time are readily available with more than a single supplier for end type device.

PREFACE

The investigation described in this report was authorized under PEMA 4932, Project No. 5751249, MIPR B5041 and TWR No. 6103. It was performed at the NASA National Space Technology Laboratories (NSTL) for the Edgewood Arsenal Resident Laboratory (EARL) and NASA-NSTL by the General Electric Company under Contract No. NAS8-27750. The conceptual design specifications were completed April 1975.

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ENGINEERING STUDY OF JET AIRMIX
FIRE SUPPRESSION

1.0 INTRODUCTION

1.1 Objective. The objective of this preliminary design study was to determine the concepts, feasibility and techniques available for pneumatic relieving and detection of fires and dust explosions in the Jet Airmix* blender. Specific considerations were given to:

- A sensing element or detection device capable of detecting ignition of bulk pyrotechnic compositions within the mixer.
- A pneumatic relief device to preclude the rupture of the mixer in the event of initiation.

1.2 Authority. The investigation described in this report was authorized under PEMA 4932, Project No. 5751249, MIPR B5041 and Technical Work Request EA-6103. It was performed for the Edgewood Arsenal Resident Laboratory (EARL) at the NASA National Space Technology Laboratories (NSTL) by the General Electric Company under Contract NAS8-27750.

1.3 Background. Previous studies[1,2] of blending white and violet smoke compositions in 2,000 and 1,000-pound quantities respectively have demonstrated that there was no apparent hazard as a result of mass detonation when subjected to high explosive donor charges. Results of this study also show that the proposed quantities of pyrotechnic compositions being handled could evolve sufficient gas pressures to warrant consideration for a fast response detection device and a relief device in order to prevent pneumatic rupture of the blender in the event of thermal ignition or a dust explosion.

This undertaking was to determine the design specifications for a detection device and a pneumatic relief device to further reduce potential hazards associated with blending colored smokes in the Jet Airmix. This study is limited to the design specifications for the installation of a pneumatic relief device and an explosion or fire detector to be installed on any proposed jet Airmix blender.

2.0 TECHNICAL APPROACH

2.1 Design Rationale. The analysis utilized to describe the specifications and requirements for a pneumatic relief and initiation detection system was predicated upon "worst case" criteria during static and dynamic operational modes of the blending cycle for colored smoke pyrotechnic compositions. Specifically, it was envisioned that the worst case con-

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* Trade name of Sprout-Waldron Company for a unit produced under a patent purchased from Grun, Lissberg, Germany.

dition for the static operational mode (see figure 1) were assumed to be:

- Slow rates of pressure rise (less than 100 psig/sec)
- Maximum relief pressure 75 psig
- Slow increase in temperature (150°F per minute)
- Maximum temperature not to exceed 1800°F

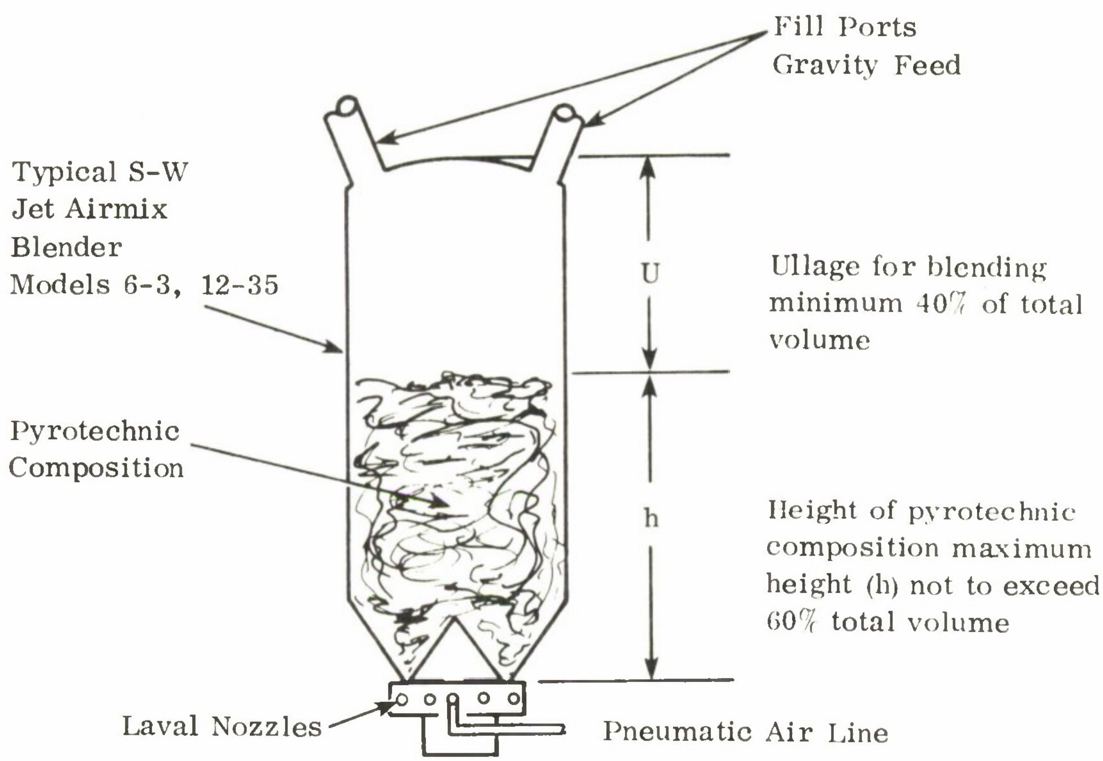

Figure 1. Jet Airmix Blender at Rest or Static Condition

The worst case condition for the dynamic operational mode (shown in figure 2) would be when a dust explosion occurred during the pulse cycle. Specifically, the conditions assumed for a dust explosion include:

- Maximum dust concentration
- Pressure rise of dust explosions not to exceed 7300 psig/sec
- Minimum ullage

- Relieving pressure (~ 8 psig)
- Maximum pressure (~ 1 spig) surging
- Reaction time less than 10 milliseconds
- Temperature at the time of explosion - ambient
- Volume of the vessel - 64 cubic feet water volume

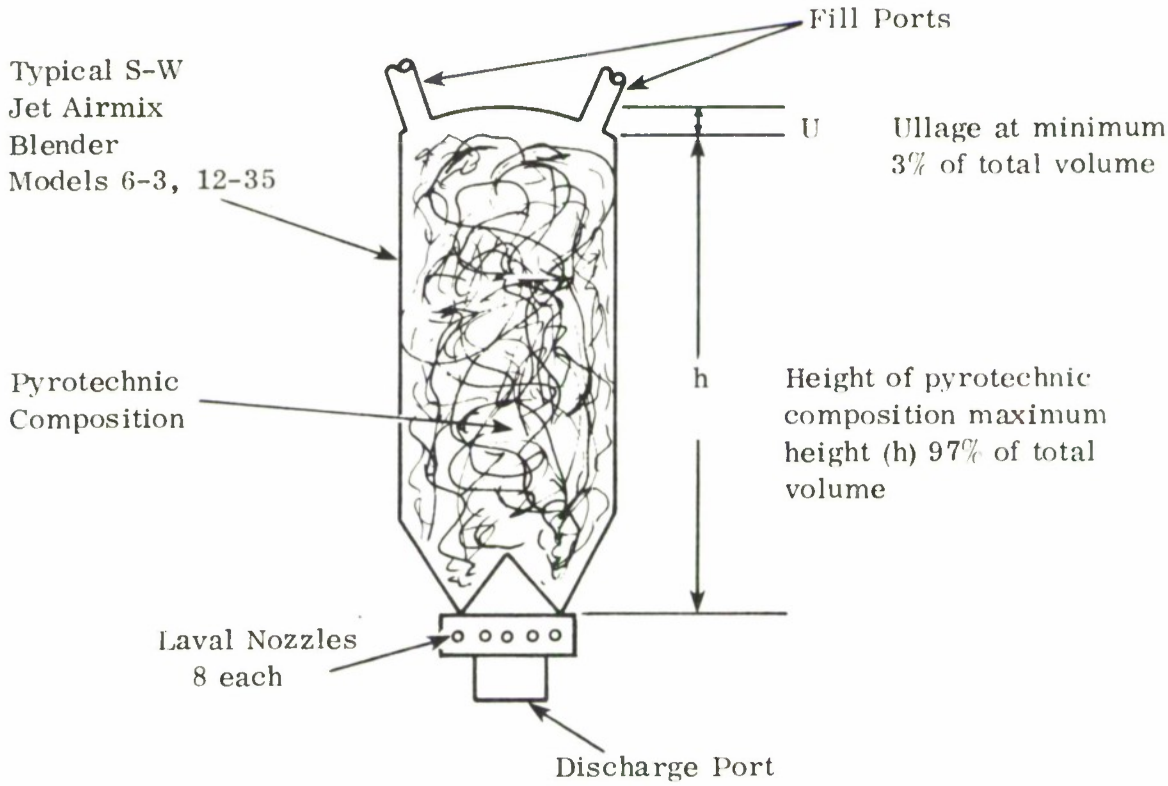

Figure 2. Jet Airmix During Pulse Cycle or Dynamic Condition

The worst case criteria typified by a dust explosion are several orders of magnitude greater than the criteria assumed in the static state operational mode therefore, the design specification of the pneumatic relief device were predicated upon the assumptions for the dynamic operational mode.

The type of initiation detector was based upon the worst case criteria of a dust explosion. Specifically, the assumptions for the detector device included:

- Source of Initiation - Friction or electrostatics

- Reaction Time - 1 - 10 milliseconds
- Pressure Rise - 7300 psig/sec maximum
- Type of Reaction - pyrotechnic dust explosion
- System Integration - users' deluge system requirement

This study was divided into three tasks to establish requirements for: (1) type and size of relief device, (2) type of initiation dector, and (3) manufacturers of available equipment.

3.0 DESIGN SPECIFICATIONS

3.1 Pressure Relief System. From the outset only a primary type relief system was envisioned. This system was a non mechanical overpressure relief device that ruptures when its rating is reached. This device was typified by a rupture disk that:

- Ruptures in less than 10 milliseconds
- Affords instantaneous maximum venting ratio upon rupture
- Installs easily with minimum cost to the user
- Is serviceable for static and surging pressures and vacuums
- Requires minimum maintenance

A typical rupture disk is shown in figure 3.

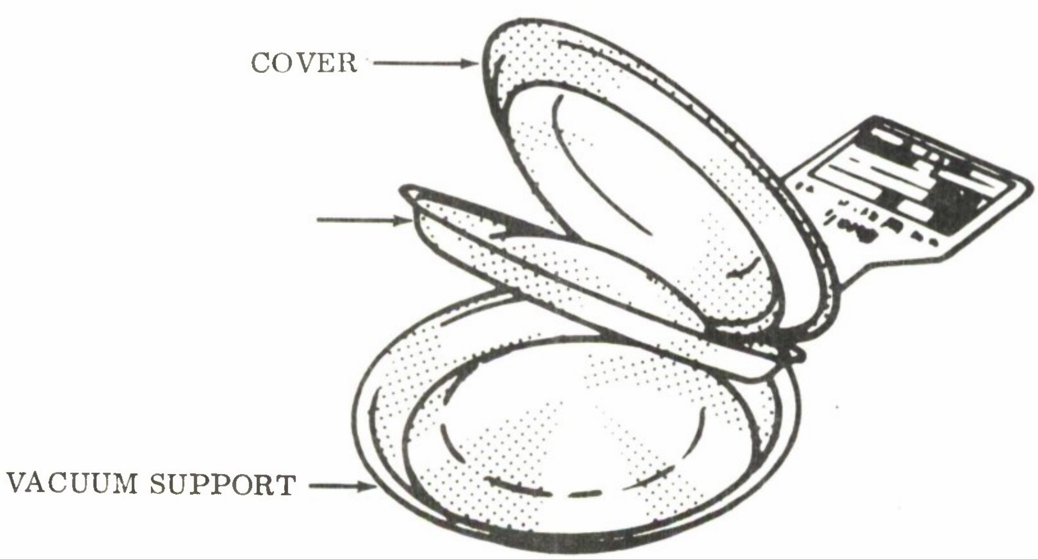

Figure 3. Typical Rupture Disk

Design specifications for sizing a rupture disk for a dust explosion include:

- Initial pressure at the time of the explosion
- Type of reactants
- Desired relief pressure
- Vent/volume ratio for the vessel being protected

The initial pressure at the time of the explosion is factory set and would range from 1 to 2 psig maximum dependent upon the operation.

The type of reactants in this case are pyromix colored smokes. The initial work performed in the Hartman Test Bomb Apparatus indicated that the pressure rate of rise for colored smokes as tested and reported in EA-DOX[3] vary from 5 psig/sec for violet smoke to 94 psig/sec for green smoke. Assuming the worst case, the most volatile constituent of colored smokes was sulfur which has a reported pressure rise varying from 2400 psig/sec to 4800 psig/sec.[4]. Thus the type of dust explosion envisioned would be less than 7300 psig/sec which typifies a ST-1 type dust. *

The initial pressure at the time of the explosion and the type of reactants are not subject to change. The rating of the rupture disk and the vent/volume ratio are subject to operational constraints.

The rating of the rupture disk was based upon the operating pressure seen inside the vessel during the dynamic operational mode. The manufacturers of rupture devices suggest that the rating of the rupture disk be 170 percent of the operating pressure. Thus the rupture disk rating would be 3.5 psig. Sprout-Waldron, the manufacturer of the Jet Airmix suggests a minimum rupture disk rating of 6 psig $\pm$ 15 percent to preclude any operational error. The rupture pressure of the vessel is stated by the manufacturer to be 325 psig; this allows for a 50:1 safety margin.

The vent/volume ratio as recommended by the National Fire Code Volume 9, Occupancy Standards and Process Hazards 68-1 through 68-53 Explosion Venting 1 through 5 is as follows:

- Small enclosures of less than 1000 cubic feet machines (blenders included) and ovens of light construction: 1 square foot for each 10 to 30 cubic feet.

Based upon this recommendation, the Jet Airmix blender would be required to have a vent opening of 2 square feet.

Utilizing tables 1a "Required Vent Area As a Function of Dust Class, Relief Pressure Pv, Container Volume and Maximum Pressure Developed During Venting (Pmax)" NFPA

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* This classification was given to dusts whose pressure rise was less than 7300 psig/sec by Bureau of Mines.

No. 681974 Explosion Venting page 68-29, a class ST-1 dust with a maximum pressure rise of 7300 psi/sec with a desired rupture pressure of 7.1 psig in a 64 cubic foot volume vessel would require a venting area of 1.4 square feet. When sizing a rupture disk for a gas the following equation *was used:

$$a = \frac{q'm \sqrt{Sg \ (T)}}{260 \ P'}$$

where

a	= required flow area in square inches
q'm	= rate of flow in cubic feet per minute at standard conditions
Sg	= specific gravity for a gas
T	= absolute temperature in degrees Rankine
P'	= rupture pressure + 10 percent in psig

Since the unknown from table 1a of NFPA No. 68 1974 is q'm, rearranging the equation as:

$$q'm = \frac{260 \ P'a}{\sqrt{Sg \ (T)}}$$

citing the values from table 1a of NFPA No. 68 1974 page 68-29 P' equals 22.51, a equals 201.6 square inches, the specific gravity of violet smoke 0.85 and the temperature T equals 600°R.

Simply substituting:

$$q'm = \frac{260x22.51x201.6}{\sqrt{0.85x600}}$$

$$q'm = \frac{1179884.1}{\sqrt{510}}$$

$$q'm = \underline{\underline{5225 \text{ SCFM}}}$$

This would readily pass the evolved gases of a colored smoke pyromix in the event of a dust explosion with roughly a 4:1 safety factor. **

A venting area of 1.4 square feet would require a rupture disk of 16 inches in diameter to be a fixed to the Jet Airmix blender. The rupture disk was placed (see figure 4) at a 60° angle from vertical near the dome to allow for safe venting and ease in cleaning the blender upon completion of the mix. (There was insufficient room on the dome to locate the rupture disk.) By specifying the placement of the rupture disk on the side at an angle minimizes modifications to plumbing to any blender in use with a minimum amount of cost.

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*Equation from BSFB Rupture Disk and Safety Head Technology Manual.

** Safety factor built into the equation when sizing for gases with L/D of 75 pipe diameter as shown downstream of rupture disk.

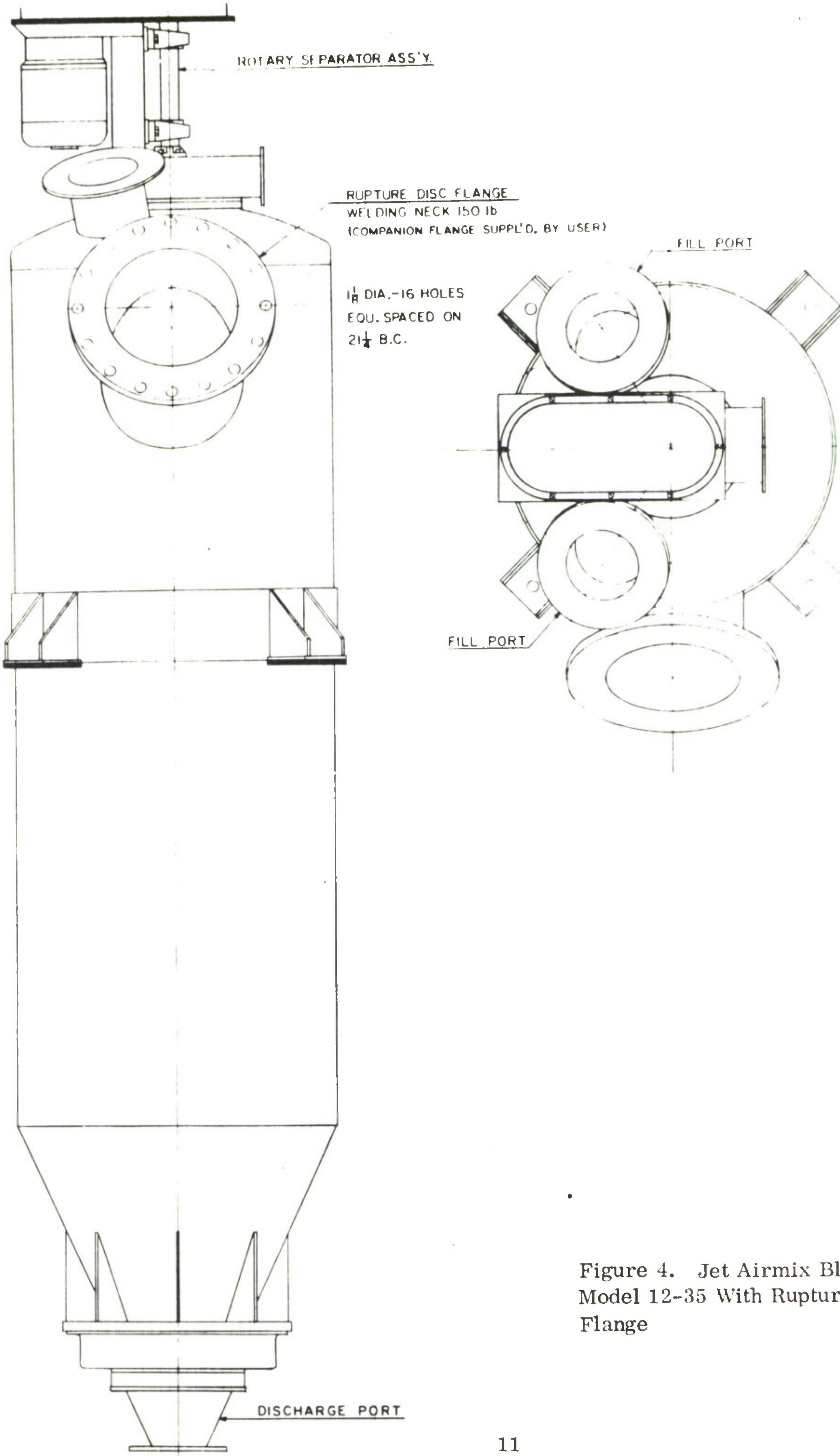

Figure 4. Jet Airmix Blender Model 12-35 With Rupture Disc Flange

Ordering information on the size and type of rupture disk with mating flange is shown in the Appendix.

3.2 Initiation Detection Device. Considering that the type of reaction being a dust explosion, the source of initiation being electrostatic, exothermic reaction or function,the type of initiation detector was limited to two types: ultra-violet detectors and infra-red detectors. Of the two types of detectors only the ultra-violet detector was available off the shelf for this reason it was chosen for further study. The advantages of this system include:

- Continuous monitoring of remote process operations for extended periods unattended
- Extended life (no moving parts)
- Rapid response - detection 1-5 milliseconds switching within 10-20 millisecond total
- Insensitivity to solar radiation
- Reacts only to flame front
- No redundant sensors required
- Economical (total system costs less than $1,000)
- Minimum maintenance

Typical installation is shown in figure 5.

4.0 CONCLUSIONS

Present state of the art technology is capable of preventing the occurrence of catastrophic events in the event of a dust explosion. Of the various types of venting devices available, only the rupture disk satisfies the criteria for venting a dust explosion. Sizing of the rupture disk is dependent upon the desired burst pressure and the volume of the vessel to be vented. This vent area/volume ratio is determined by the users application and model of jet "Airmix" blender. The type of initiation detection device required to meet prescribed time frame for detection and actuation of a deluge or suppressant system is an ultra-violet type detector and associated control systems. The manufacturers' survey indicates that off-the-shelf items with minimum delivery time are readily available with more than a single supplier for each type device.

A total pneumatic and initiation detection system is feasibly economical over a wide range of applications and user conditions. Various manufacturers were contacted to determine what the cost, availability, ordering information was readily available for safety heads (rupture disks) and initiation detector systems. Manufacturers who provided feedbacks are listed on page 13.

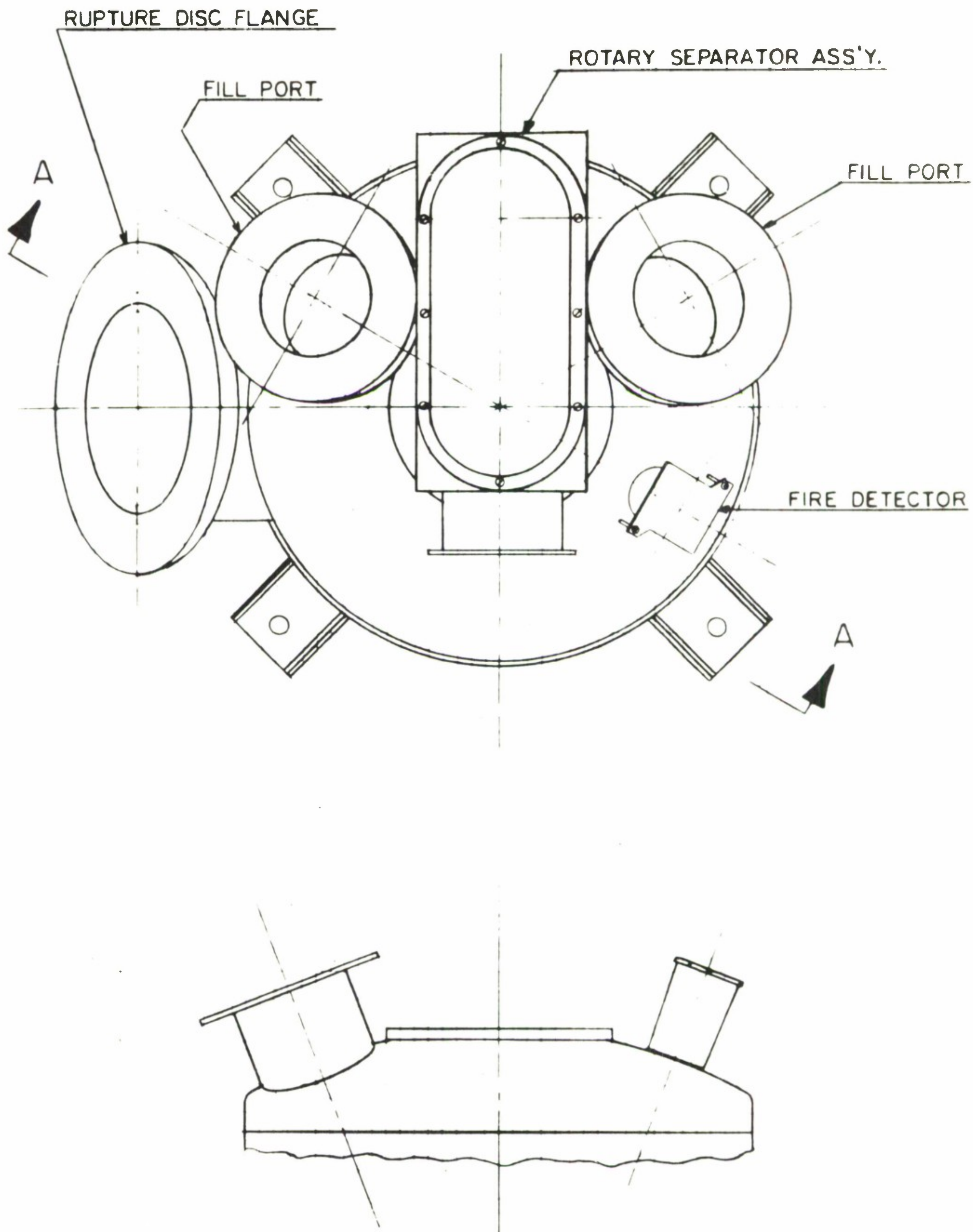

Figure 5. 12-35 Sprout-Waldron Jet Airmix with Det-tronics Model C7037 Ultraviolet Dector Attached to the Dome

List of Available Suppliers

Supplier	Products Available
Fike Metal Products Blue Springs, Missouri	Rupture Discs Deluge Valves Suppression Systems
Continental Disc Corp. Kansas City, Missouri	Rupture Discs
B&B Safety Systems Tulsa, Oklahoma	Rupture Discs
Fenwall Corporation Ashland, Mass.	Sensors IR & UV/ System and Component Design upon request
Det-Tronics Corp. Minneapolis, Minn.	Sensors UV and Control Circuits, Deluge Systems

5.0 RECOMMENDATIONS

This study was cursory in nature and only considered the burst disk sizing for two models of the Jet Airmix blender. These models were the S-W 6-3 and S-W 12-35 which are known to be in existence and used in the manufacture of pyrotechnics. Since the current models are not installed in operating lines for the production of colored smoke pyrotechnic composition,user facility and as built drawings were not available to make specific recommendations. Furthermore, no actual tests were performed to validate the sizing which was predicated solely upon vent/volume ratios for a specific type of Class St-1 dust with relatively low pressure rise psig/second.

- Full-scale test to validate sizing
- Additional tests for each proposed pyromix
- The suppressant or deluge system to be external to the mixer
- The placement of the rupture disk to be such that it does not interface with kinetics or blending process.
- Secondary venting to atmosphere rather than ducting which would require additional sizing specifications if ducting is used.
- Detailed analysis of the full-scale production facility to include the venting, detection and the deluge system for total system investigation.

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1. F. L. McIntyre, EA-4D21. Identification and Evaluation of Hazards Associated with Blending of HC White Smoke by Jet Airmix Process. January 1974.

2. F. L. McIntyre, EM-CR-75001, EA-4D91. Identification and Evaluation of Hazards Associated with Blending of Violet Smoke Mix by Jet Airmix Process. March 1975.

3. W. R. Wilcox, EA-FR-1D0X. Pyrotechnic Dust Sensitivity Testing Program. 30 June 1973.

4. NFPA No. 68. Explosion Venting 1974. pp. 68-28-30. National Fire Protection Association. 1974.

APPENDIX

ORDERING INFORMATION
FOR CPV-C RUPTURE DISC
FROM
FIKE METAL PRODUCTS, INC.
BLUE SPRINGS, MISSOURI

Attachment 1

	S-W Model # 6-3	S-W Model # 12-35
Type	CPV-C	CPV-C
Size	8"	16"
Rupture Pressure Ambient +25-0°F	8 psig nominal	8 psig nominal
Material		
Seal	Aluminum	Aluminum
Support	304SS	304SS
Cover	304SS	304SS
Disc Holder		
Pipe Size	8"	16"
Material	304SS	304SS
ANSI Rating (ASA)	150	150
Maximum Rating	240	275
Outside Diameter	10-7/8"	20-1/8"
Overall Height	2-1/8	2-7/8
Number of preassembled screws	3	4

Companion flanges to hold the disc holder and CPV-C rupture disc are supplied by user.

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